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Improvement of Latex Quality Using Locally-Produced Organic Fertilizer from Rubber Processing Sewage Sludges

Riwandi[1], Prasetyo[1], Hasanudin [1], Indra Cahyadinata[1],
Ali Munawar[1] and Rachma Doni[2]

[1]Faculty of Agriculture, University of Bengkulu, 38371A, Indonesia
[2]PT Perkebunan Nusantara VII (Persero) Bengkulu, Indonesia
e-mail:riwandi_unib@yahoo.co.id

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ABSTRACT

Most of rubber plants in Indonesia are cultivated in highly-weathered soils; therefore, their annual productions are relatively low with the low quality of latex. The aim of this reseach was to increase the latex quality from a rubber plantation grown on low fertility soils by applying a locally-produced organic fertilizer (LOF) to the soils. This research consisted of two steps, *i.e*. LOF production and a field fertilization experiment. The LOF was made mainly from waste of a latex processing industry. The field fertilization experiment was conducted to assess the effects of LOF additions to the soils on the latex quality. The field experiment was performed using a randomized complete block design with 6 LOF levels, 4 levels of land slopes, and 5 rubber trees in each block, resulting in 120 rubber trees. The LOF levels were 0, 10, 20, 30, 40, and 50 kg tree^{-1}. The LOF contained 17.35% organic-C, 1.14% total-N, 0.53 ppm available-P, and 1.21 cmol (+)kg^{-1} exchangeable-K, with slightly alkaline pH (pH 8.0). The soil has low fertility status as indicated by the low amounts of total-N and exchangeable base cations (K, Na, and Mg), and very acid pH (pH 4.5). Indicators of latex quality comprising of blockage index, ash-, impurity- and dry rubber-content, and N, P, K contents in the rubber leaves were measured. Although there were no significant differences in most observed latex properties due to LOF addition, their values tended to be higher when the rubber trees were fertilized with LOF. Apparently N and K contents in the rubber leaves are better correlated to the latex properties compared to the P content.

Keywords: Latex, locally-produced organic fertilizer, rubber tree

ABSTRAK

Pada umumnya tanaman karet di Indonesia dibudidayakan pada tanah mineral yang berpelapukan lanjut sehingga produksi dan kualitas getah karet setiap tahun relatif rendah. Tujuan penelitian ini adalah untuk meningkatkan kualitas getah tanaman karet yang dibudidayakan pada tanah yang kesuburannya rendah yang diaplikasikan dengan pupuk organik lokal dari limbah karet. Penelitian ini terdiri atas 2 tahap, yaitu (1) produksi pupuk organik lokal dari limbah karet, dan (2) percobaan pemupukan pada perkebunan karet rakyat. Pupuk organik lokal dibuat dari limbah karet asal pabrik pengolahan karet yang dicampur dengan kotoran sapi dan diinkubasi selama 6 minggu. Penelitian pemupukan di kebun karet rakyat untuk menguji pengaruh pupuk organik lokal dilakukan dengan menggunakan Rancangan Acak Kelompok Lengkap (RAKL) dengan 6 dosis pupuk organik lokal, 4 tingkat lereng (puncak, lereng atas, lereng bawah, dan lembah) sebagai blok, dan 5 pohon karet setiap blok, sehingga diperoleh 120 pohon karet sampel. Dosis pupuk organik lokal yang diaplikasikan untuk setiap pohon karet adalah sebagai berikut: 0, 10, 20, 30, 40, dan 50 kg. Hasil analisis menunjukkan bahwa pupuk organik lokal dari limbah karet mengandung C-organik 17,35%, N-total 1,14%, P-tersedia 0,53 ppm, K-dapat ditukar 1,21 cmol(+)kg^{-1}, dan pH 8,0. Kesuburan tanah pada kebun karet sangat rendah karena N-total dan kation basa dapat ditukar (K, Ca, Mg) tergolong rendah, dan pH tanah sangat masam (pH 4,5). Indikator kualitas getah karet yang terdiri dari indeks penyumbatan (IP), kadar abu, kadar kotoran, kadar karet kering (KKK), dan kandungan N, P, K pada daun karet telah diukur. Hasil pengukuran indikator kualitas getah dan kandungan unsur N, P, K pada daun karet tidak beda nyata antar perlakuan dosis pupuk organik lokal, tetapi terdapat kecenderungan hasil getah karet yang lebih tinggi ketika tanaman karet diberi pupuk organik lokal. Selain itu, terdapat korelasi yang lebih baik antara kadar N dan K pada daun karet dengan indikator kualitas getah karet dibandingkan dengan korelasi kadar P pada daun karet dengan indikator kualitas getah karet.

Kata Kunci: Getah karet, pupuk organik lokal, pohon karet

INTRODUCTION

Rubber tree (*Hevea brasiliensis*) is one of the most important and strategic agricultural commodities in Indonesia. The major cultivation of rubber tree in Indonesia is performed by house-hold farming (83%), followed by private plantation (9%), and state-owned plantation (8%) (Setyamidjaja 1993; Siregar and Suhendry 2013; Sampoerno *et al.*2015). As a major producer, however, the average production of the house-hold farming is very low, *i.e.* 300-400 kg ha^{-1}, compared to the other two producers that have achieved 1500 kg ha^{-1} (Siswoputranto 1981). Low productivity of the rubber tree under house-hold farmings is generally associated with the lack of agricultural inputs such as the low amount of fertilizer application and simple tapping technology use, cultivation in fragile and steep sloping lands with poor soil, and the use of low-yield plant species (Anonim 1992; Siagian 2011).

Currently Indonesia has been developing rubber tree clones with higher production from generation 1 to 4. The actual production of the generation 1 varies from 500 to 750 kg ha^{-1} yr^{-1}, the generation 2 from 1000 to 1500 kg ha^{-1} yr^{-1}, the generation 3 from 1500 to 2000 kg ha^{-1} yr^{-1}, and the generation 4 from 2000 to 2500 kg ha^{-1} yr^{-1} (Woelan *et al.* 2006). The rubber clone used in this experiment is from the generation 3, clone PR 261 (Personal Communication 2016). Most rubber tree plantations in Indonesia are cultivated in low fertility soils with low phosphorus, low organic matter content, acidic pH, and susceptible to erosion. In Bengkulu Province, for example, the rubber plantation is widely spread on Ultisols with high rainfall (>3000 mm yr^{-1}) and various topography.

Several efforts have been developed to improve latex quality such as intensification, extensification, and rehabilitation. Intensification has been conducted through seed quality improvement and fertilizer addition. One of the promosing efforts is the addition of locally-made organic fertilizer (LOF). This organic fertilizer can be produced from waste materials from latex processing. A study conducted by Riwandi *et al.* (2016) reported that this waste contains 62.76% total organic-C, 1.10% total-N, 0.81% total-P, and 0.24% total K. This waste, therefore, is a potential material for organic fertilizer production.

Latex comprises of serum and thin layer protein that coating rubber particles. The serum contains protein, minerals, and enzymes; while rubber particles are cis-1.4-polyisoprenes coated with protein that can create charges (Verheye 2017). Latex is colloidal suspension containing protein, lutoid, alkaloid, carbohydrate, glucose, polyisoprene, oil, tannin, rezine, and gum (Verheye 2017).

The study was aimed to improve latex production and its quality by applying organic fertilizer produced from a locally-available waste from latex production.

MATERIALS AND METHODS

Experimental Setup

The study was conducted in two stages, *i.e.* production of a locally-produced organic fertilizer (LOF) and followed by a field fertilization study using the produced LOF. The LOF was produced mainly from latex processing wastes obtained from a latex industry owned by a state-owned company (PT Perkebunan Nusantara VII) in Padang Pelawi, Bengkulu, Indonesia. Meanwhile, the fertilization study was conducted in a private rubber plantation in Tanjung Teranda, Pondok Kubang, Bengkulu Indonesia. All the study stages were carried out in March until August 2016.

Production of Locally-Produced Organic Fertilizer

The waste of the latex processing was mixed with cattle manure in a ratio of 1:1 and put in a soil pit of 5 m (length) × 2 m (wide) × 1 m (depth). The *effective microorganism* 4 (EM4) comprising sugar and urea incubated overnight was added to the waste-manure mixture. The composting process of waste was weekly monitored for its color (*Munsell's Soil Color Chart*), odor, pH (pH universal indicator scale 0-14, Merck, Germany), water content (gravimetric method), and temperature (Hg Thermometer) for six weeks. The produced organic fertilizer was, then, so-called locally-produced organic fertilizer (LOF). The LOF was considered mature as it was brownish-black (*Munsell's Soil Color Chart* 10YR2/1 to 10YR2/2), odorless, neutral pH (pH 7), with the water content less than 50% (w/w) and the temperature around 30^{o}C (Riwandi *et al.* 2012).

A Field Fertilization Study

The fertilization study was conducted in a randomized complete block design (RCBD) consisting of 6 LOF levels, 5 rubber tree plants, and 4 levels of land slopes (top, upper level, lower level, and foot plain) as blocks, resulting in 120 experimental rubber plants. The 6 LOF levels were 0, 5, 10, 15, 20 and 25 Mg ha^{-1}, which were equivalent to 0, 10, 20, 30, 40, and 50 kg tree^{-1}, respectively. The organic fertilizer was applied in bands at 20-cm soil depth with 1 m distance surrounding tree stem bases. Micronutrient fertilizer containing iron (Fe) and copper (Cu) at 18.6 g tree^{-1} (equivalent to 10 kg ha^{-1}) was dissolved in 1L deionized water and added to the banded organic fertilizer at each tree. In addition, macroelement fertilizers including urea, SP-36, and KCl at levels of 186 g tree^{-1} (100 kg ha^{-1} urea), 93 g tree^{-1} (50 kg ha^{-1} SP-36), and 93 g tree^{-1} (50 kg ha^{-1} KCl) were surface broadcasted surrounding 120 experimental rubber plants.

Soil, Plant and Latex Analyses

The soil characteristics including organic-C (Walkley and Black method) (Nelson and Sommers 1982), total-N (Kjeldahl Method) (Bremmer and Mulvaney 1982), C/N ratio, available-P (Bray 1 method) (Olsen and Sommers 1982), exchangeable-K (Ammonium Acetate 1 N extraction method) (Thomas 1982), exchangeable-Al (KCl 1 N extraction) (Barnhisel 1982), Al saturation, cation exchange capacity (CEC) (Ammonium Acetate 1 N extraction method) (Rhoads, 1982), and soil pH (H_2O) (soil:distilled water ratio of 1:2.5) (McLean, 1982) were measured. In addition, the nutrient content in the rubber leaves including total N (Micro Kjeldahl method) (Soil Science Lab, University of Lampung, 2017), P and and K concentrations (Combustion method) (Soil Science Lab, University of Lampung, 2017) was measured. Moreover, the latex properties including blockage index (ratio between latex flow at the first 10 minutes and total volume of the latex within 3 hrs, starting from tapping) and ash content were measured. Ash content and its impurity were determined using a method developed by a Laboratory in PT Perkebunan Negara VII (PTPN 7 2014). Other latex properties including dry rubber content (DRC = ratio between latex dry weight and latex fresh weight multiplied by 100%); latex fresh weight (LFW = total latex dry weight after 3 hrs from tapping); latex ground weight (LGW = latex fresh weight after being ground with machines forming thin sheets), and latex dry weight (LDW = ground latex dried in an oven at 70 ^{o}C for 12 hrs) were measured. Lipid, protein, and carbohydrate contents of dry latex were determined in the Agricultural Engineering Laboratory at the University of Lampung, Lampung, Indonesia.

Data Analysis

The collected data were statistically analyzed using the Analysis of Variance at á = 5%, and further analyzed using DMRT (*Duncan's Multiple Range Test*).

RESULTS AND DISCUSSIONS

Description of the Study Site

The soil properties of the rubber plantation are darkish brown and humid, fine texture, crumb structure, low bulk density (topsoil 0.89 Mg m^{-3} and subsoil 1.01 Mg m^{-3}), moderate organic matter content, low total-N (0.20%), high available-P (16.8 ppm), low exchangeable-K (0.25 cmol(+)kg^{-1}), moderate exchangeable-Ca (6.24 cmol(+)kg^{-1}), low exchangeable-Mg (0.81 cmol(+)kg^{-1}), low exchangeable-Na (0.08 cmol(+)kg^{-1}), and acidic pH (pH 4.5). The rubber plantation field is located at a slope of <30% with moderate crop coverage (65-74%), weak erosion rate, green growing vegetation, and moderate earthworm population. The results indicate that the fertility status of the soil is low and therefore additional fertilizer is necessary.

Table 1. Properties of cattle manure and latex processing waste before composting.

Fertilizer	pH	Organic C (%)	Total N (%)	Available P (ppm)	Exchangeable K (cmol(+)kg^{-1})
Cattle Manure	7.4	15.71	1.20	0.58	4.98
Latex Processing Waste	6.6	62.76	1.10	0.81	0.24

Table 2. Nutrient content of the LOF composted for 1.5 months.

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LOF	Organic C (%)	Total N (%)	Available P (ppm)	Exchangeable K (cmol (+)kg^{-1})	pH
Sample 1	18.99	0.95	0.54	-	8.0
Sample 2	15.71	1.33	0.53	1.21	8.0
Average	17.35	1.14	0.53	1.21	8.0

Table 3. Average content of organic-C, total N, C/N ratio, available P (Bray 1), exchangeable Al, Al-saturation, CEC, and pH (H_2O) of the soil at the rubber plantation at the end of the experiment (August 31, 2016).

LOF levels Mg ha^{-1}	Organic C (%)	Total N (%)	C/N Ratio	Available P (ppm)	Exchangeable Al cmol(+)kg^{-1}	Al saturation (%)	CEC cmol(+)kg^{-1}	pH (H_2O)
0	2.17	0.19	11.42	11.35	2.20	28.53	7.71	4.2
5	2.55	0.24	10.63	6.91	1.81	17.87	10.13	4.3
10	3.09	0.27	11.44	17.85	2.59	21.33	12.14	4.4
15	2.01	0.18	11.17	4.71	2.29	30.74	7.45	4.2
20	2.45	0.20	12.25	7.07	3.18	30.23	10.52	4.2
25	3.07	0.23	13.35	19.15	1.14	13.62	8.37	4.4

Properties of Locally-Produced Organic Fertilizer

Table 1 shows properties of raw materials of LOF. The results show that the cattle manure has neutral pH (pH 7.4) and contains high amounts of organic-C, total-N and exchangeable-K, but low in available P. The pH of latex processing waste is around neutral (pH 6.6) and contains very high amount of organic-C, high amount of total-N, and low amounts of available-P and exchangeable-K. The compost produced from latex waste has water content >50% (dry weight/dry weight), darkish brown colour (*Munsell's Soil Color Chart*, 10YR2/1 and 10YR2/2), coarse fractions, slightly odor, and slightly alkaline pH (pH 8.0). This means that the compost made from latex processing waste meets the criteria of a high quality compost (Isroi 2008). The dark color indicates high organic matter content and slightly alkaline pH, while the gas odor indicates the on-going decomposition process (HIDRA 1998, 2001; Riwandi *et al.* 2015). The compost maturity was tested using palm and finger squeezing and feeling (Riwandi *et al.* 2012). If water did not flow out among fingers, the compost was considered mature. The whole composting process took 1.5 months and the odor was easily eliminated by air-drying.

The nutrient content and pH of the compost are presented in Tabel 2. Table 2 indicates that the quality of the compost is good as indicated by very high organic-C content, followed by the moderate content of exchangeable-K, total-N, and available-P. The quality of the compost used in our study is comparable with the previously-made compost from other studies (Isroi 2008; Fernando 2012).

Table 4. Average total content and amount of N, P, and K in the rubber leaves at the end of the experiment (August 31, 2016).

LOF Level Mg ha^{-1}	N Content (%)	N Amount kg ha^{-1}	P Content (%)	P Amount kg ha^{-1}	K Content (%)	K Amount kg ha^{-1}
0	2.68	5360	0.22	440	0.88	1760
5	2.73	5460	0.23	460	0.99	1980
10	2.59	5180	0.23	460	1.27	2540
15	2.66	5320	0.23	460	1.13	2260
20	2.78	5560	0.23	460	1.29	2580
25	1.71	3420	0.22	440	1.04	2080

Table 5. Latex properties at the end of experiment.

LOF Level ($Mg\ ha^{-1}$)	Latex Properties											
	BI (%)	Ash (%)	Impurity (%)	Dry Rubber Content (g)	Volume Latex at 10 min (cc)	Total Volume Latex (cc)	Latex Fresh Weight (g)	Ground Latex Weight (g)	Latex Dry Weight (g)	Lipid Content (%)	Protein Content (%)	Carbohydrate Content (%)
0	38.03a	0.40a	0.04a	27.98a	11.85a	40.20a	49.08a	18.80a	14.19a	4.20a	1.64a	93.26a
5	39.44a	0.38a	0.03a	27.45a	15.45a	47.00a	51.58a	18.84a	14.85a	4.35a	2.17a	92.42a
10	41.90a	0.38a	0.02a	29.90a	13.45a	35.15a	44.13a	19.20a	13.76a	4.25a	1.95a	92.77a
15	37.68a	0.34a	0.01a	29.72a	17.05a	53.50a	59.67a	25.71a	19.07a	4.37a	1.44a	93.10a
20	26.27a	0.47a	0.01a	27.53a	13.45a	53.85a	62.09a	25.18a	18.73a	4.10a	1.92a	92.74a
25	45.21a	0.34a	0.01a	29.87a	18.90a	42.10a	53.21a	20.99a	16.21a	4.10a	2.28a	92.50a

Notes: Values in the same column followed by the same letters indicate no significant difference based on *Duncan's Multiple Range Test* at 5% significance level.
BI = Blockage Index

Soil Properties after Fertilization

The chemical properties of the soil at the end of the fertilization experiment are presented in Table 3. Table 3 shows that organic-C content of the soil increased with the increase of the dose of LOF applied. The highest soil organic-C content was measured after application of 10 $Mg\ ha^{-1}$ LOF and the lowest soil organic-C content, which was lower than that in the control plot (2.17% organic-C), was measured after application of 15 $Mg\ ha^{-1}$ LOF. The total-N content in the soil increased with LOF application from 5 to 25 $Mg\ ha^{-1}$, except that in the application of 15 $Mg\ ha^{-1}$ LOF in comparison to that without LOF application (control plot). The results indicate that the LOF application at 10 $Mg\ ha^{-1}$ was better in supplying N (*i.e.* from 0.19% to 0.27%) than other LOF rates. The C/N ratio of the soil was similar among different doses of LOF application, ranging from 10.63 to 13.35 and comparable to the C/N ratio of most soils. The amount of available-P (Bray 1) of the soil varied with LOF addition, and was more than the amount of available-P in the normal soils, *i.e.* 1 ppm as reported by Prasad and Power (1997).

Field observation indicated that the rubber plants showed no P deficiency symptoms. The lowest amount of exchangeable-Al (1.14 $cmol(+)kg^{-1}$) and Al-saturation (13.62%) of the soil were measured after application of 25 $Mg\ ha^{-1}$ LOF. The highest Al-saturation (30.74%) was measured after application of 15 $Mg\ ha^{-1}$ LOF. The study of Prasad and Power (1997) indicated that the soil with pH 4.2 and Al-saturation 60% can cause toxicity to roots. Soil CECs under all LOF rates were low (<12.5%); and therefore, the base cations in this soil were subjected to leaching, resulting in low soil fertility status. The soil was dominated by kaolinite clay minerals and Fe/Al oxides/hydroxides (Hodges 2012) and acidic pH. Although the LOF addition did not increase the soil pH, the amount of exchangeable-Al tended to decrease particularly in the soil applied with 25 $Mg\ ha^{-1}$ LOF. The organic-C derived from LOF might have neutralized the exchangeable-Al to an acceptable level.

Nutrient Content in the Rubber Leaves

The nutrient content in the rubber leaves due to LOF addition are presented in Table 4. Total N and P contents in the leaves were not significantly affected by LOF addition, but their contents were in the normal range of N and P contents in the rubber plants. In contrast, total K content in the leaves increased with the increase of LOF doses applied to the soil, and the highest total K content in the leaves (1.29% or 2580 $kg\ ha^{-1}$) was measured after application of 20 Mg ha^{-1} LOF to the soil. The total K content in the leaves about 1.29% or 2580 kg ha^{-1} was in the normal range of K content in the rubber plants.

Latex Properties

The properties of latex measured in this study are presented in Table 5.

Blockage Index (BI): There were no significant differences among blockage indexes (BI) of latex due to LOF addition. However, the lowest BI of latex (26.27%) was measured after application of 20 Mg ha^{-1} LOF to the soil, and the highest BI (45.21%) was measured after application of 25 Mg ha^{-1} LOF. There have been no explanation why the highest blockage index of latex ocurred in the plot applied with 25 Mg ha^{-1} LOF. However, the high LOF amount applied to the soil might have caused blockage acceleration and destroyed lutoid fraction in the latex.

Ash Content in Latex: Ash content indicates the mineral content in latex. There were no significant differences on the ash contents in the latex after application of LOF to the soil. The average ash content was very low (<0.50%), but still in the normal range of ash content in latex.

Impurity Content: The impurity content of the latex was not significantly influenced by LOF addition to the soil. The impurity content is still acceptable under LOF additions of 5 to 25 Mg ha^{-1}, namely < 0.03%. The results indicate that the latex quality is best with LOF additions at 5 to 25 Mg ha^{-1}. The study of Stevens and Stevens (1933) showed that the acceptable impurity content of latex is 0.03%, which is indicated by the gray color, not white.

Dry Rubber Content (DRC): Although there were no significant differences on the DRC due to LOF addition to the soil, the DRC tended to be higher after application of 10, 15, and 25 Mg ha^{-1} LOF

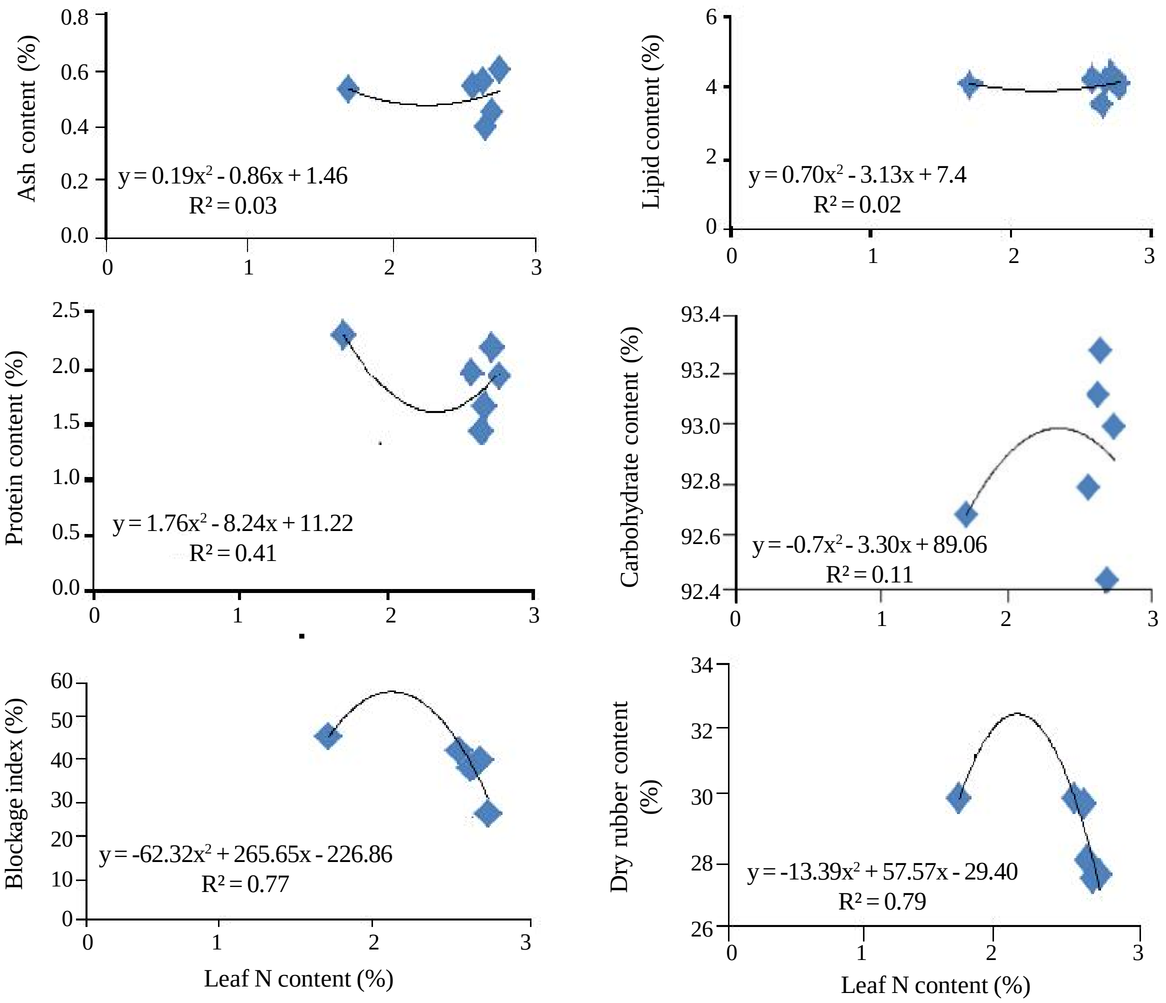

Figure 1. Correlations between N content in the rubber leaves and ash, lipid, protein, carbohydrate, blockage index, and dry rubber content in the latex.

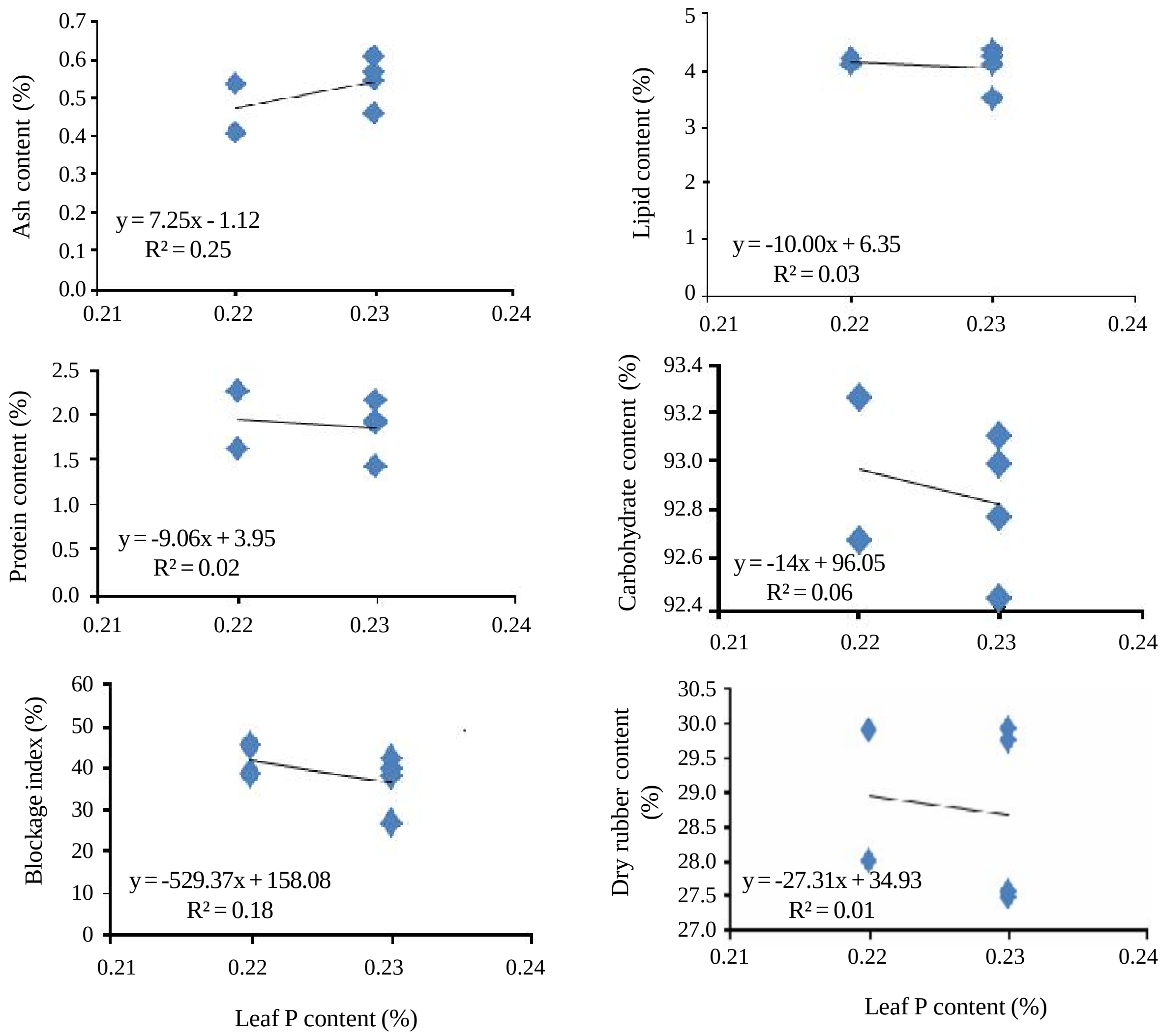

Figure 2. Correlations between P content in the rubber leaves and ash, lipid, protein, carbohydrate, blockage index, and dry rubber content in the latex.

enriched with micronutrients. The higher the dry rubber content, the shorter the molecular distance and the lower the water content in the latex are (Elly 2006).

Latex Volume at 10 Minutes: There were no significant differences on the latex volumes at 10 minutes due to LOF addition to the soil. However, the latex volumes tended to be higher at 5 to 25 Mg ha^{-1} LOF application than that without LOF application (control plot). Previous works reported that the latex flow velocity is influenced by the blocking index (Jacob *et al.*1989), lutoid stability and water influx in the latex flow area (Pakianatan *et al.*1989).

Total Volume of the Latex: There were no significant differences on the total volumes of the latex due to LOF addition to the soil. However, the volumes of the latex tended to be higher at 5 to 25 Mg ha^{-1} LOF application, except that in the 10 Mg ha^{-1} LOF application, which was lower than that in the control plot.

Latex Fresh Weight: Application of LOF to the soil did not significantly affect the latex fresh weight. However, the latex fresh weight tended to increase after application of 5 to 25 Mg ha^{-1} LOF, except that in the 10 Mg ha^{-1} LOF application, which was even lower than that in the control plot. The trend of the latex fresh weight is very similar to the trend of latex volume as previously described.

Ground Latex Weight: There were no significant differences on the ground latex weight due to LOF addition to the soil. However, the result showed a slight increase on the ground latex weight after application of LOF above 5 Mg ha^{-1}. The LOF might have slightly provided more nutrients to plants.

Latex Dry Weight: There were no significant differences on the latex dry weight due the LOF

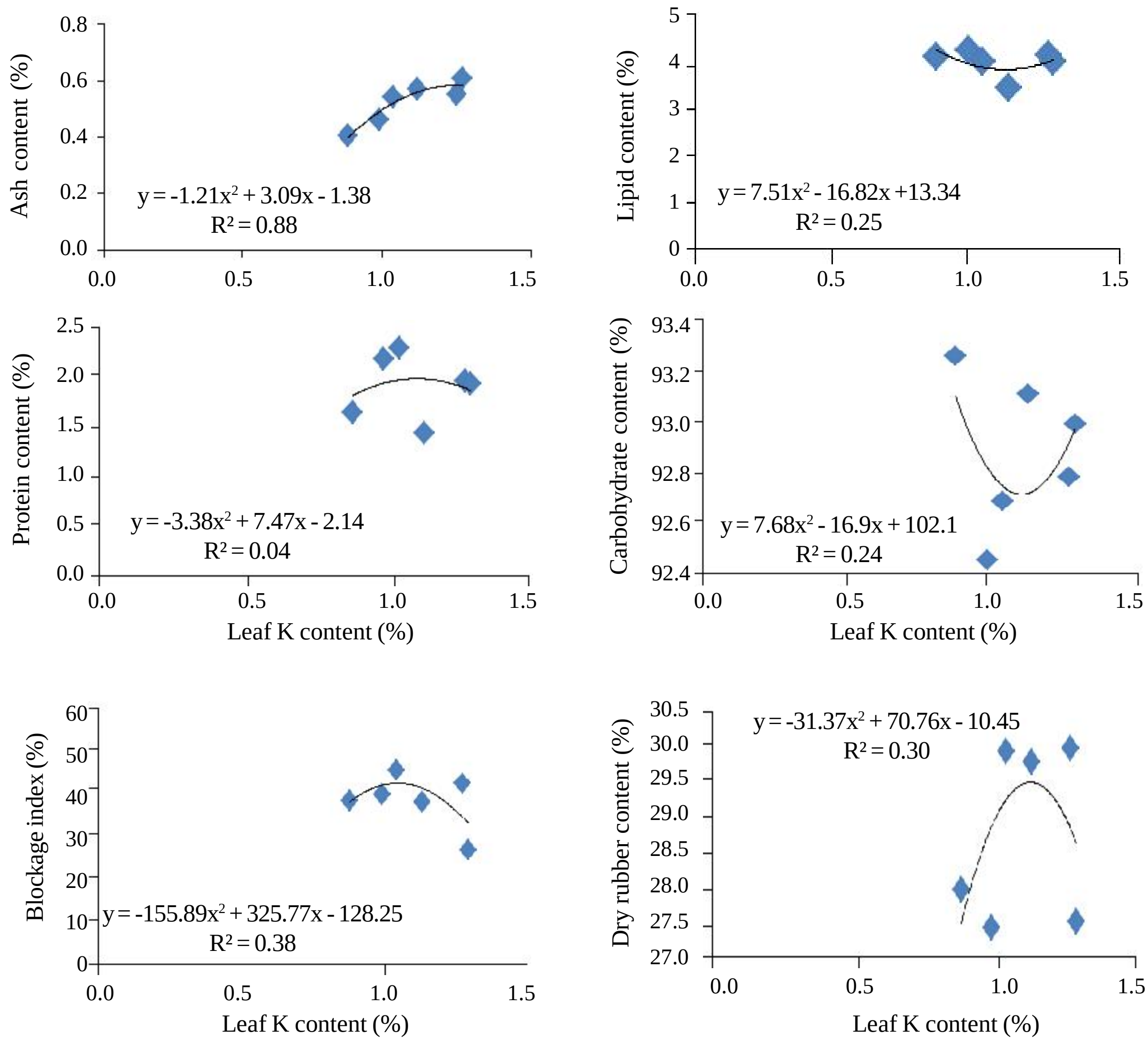

Figure 3. Correlations between K content in the rubber leaves and ash, lipid, protein, carbohydrate, blockage index, and dry rubber content in the latex.

additions from 0 to 25 Mg ha^{-1} to the soil. Nevertheless, the results showed that the latex dry weight tended to increase after application of 5 to 25 Mg ha^{-1} LOF, except that in the 10 Mg ha^{-1} LOF application. This fact is similar to the data of dry latex content.

Lipid Content in the Latex: There were no significant differences on the lipid contents in the latex due to LOF additions from 0 to 25 Mg ha^{-1} to the soil, although the lipid contents in the latex tended to increase with the addition of 5 to 15 Mg ha^{-1} LOF. However, at 20 and 25 Mg ha^{-1} LOF application, the lipid contents were not different from that in the control plot. Latex consists of very fine hydrocarbon particles and serum. The hydrocarbon usually associates with about 3% of resin, and some protein (N and albumin). The resin contains lipid acid, 50% from which as stearic oleic acid, and linoleic acid, which protect the hydrocarbon from oxidation. Serum contains white crystalines from water soluble quebrachitol or l-methyl-inositol, alcohol, or others (Stevens and Stevens 1933).

Protein Content in the Latex: There were no significant differences on the protein contents in the latex among LOF dose applications from 0 to 25 Mg ha^{-1}, although the contents tended to increase with LOF addition above 5 Mg ha^{-1}, except that in the application of 15 Mg ha^{-1} LOF, which was not different from that in the control plot. In the latex, protein functions as a natural stabilisator, although it is readily to decompose. Stevens and Stevens (1933) reported that in the tropics addition of coagulator is necessary to prevent protein from decomposition.

Carbohydrate Content in the Latex: Although the results of statistical analysis showed no significant differences on the carbohydrate contents in the latex among LOF dose applications, the data tended to decrease with the increase of LOF doses applied. This might explain that LOF addition had increased the efficiency of photosynthesis.

Plant Nutrition and Latex Properties

The correlations between nutrient contents in the rubber leaves and latex properties are presented in Figure 1, 2, and 3. Apparently N and K contents in the rubber leaves is better correlated to the latex properties compared to the P content. Nitrogen (N) content is positively correlated to the dry rubber content and blockage index of the latex, and slightly correlated to the protein content in the latex. The range of N content in the rubber leaves measured in this study is 1.71% up to 2.73%. The critical level for N content in the rubber leaves is 3.00% (low content) (George and Jacob 2000; Njukeng 2014). Because the low N content in the rubber leaves, therefore the protein is slightly formed.

Potassium (K) content in the rubber leaves is positively well correlated to the ash content in the latex and slightly correlated to the blockage index of the latex, dry rubber content, protein content and corbohydrate content in the latex. The sufficiency range of K content in the rubber leaves measured in this study is 0.88% up to 1.27%. Similarly, the sufficiency range used for diagnosis of K in rubber leaves is 1.0% up to 1.5% (Karthikakuttyamma *et al.* 2000 and Jessy 2011). In plants, potassium acts in the activation of enzyme systems related to photosynthesis and respiration (Correia *et al.* 2017; Ahmad *et al.* 2012; Cakmak *et al.* 2005; Ashraft *et al.* 2001), especially the synthesis of protein (Correia *et al.* 2017; Ashraf *et al.* 2001) and carbohydrate (Correia *et al.* 2017; Pettigrow 2008).

Phosphorus content is weakly negatively correlated to lipid, protein, carbohydrate, blockage index, and dry rubber content of the latex. This phenomenon is probably due to the P contents in the rubber leaves measured in this study, which are around 0.22% up to 0.23%, are in the medium range of P content in leaves. According to Njukeng 2014, P is incorporated into organic compounds, including nucleic acids (DNA and RNA), phosphoproteins, phospholipids, sugar phosphates, enzymes, and energy-rich phosphate compounds like adenosine triphosphate.

CONCLUSIONS

Although statistically not significant, improvement in the latex quality and soil properties due to the addition of LOF made from rubber plantation wastes enriched with micronutrients (Fe and Cu) was observed. Apparently N and K contents in the rubber leaves are better correlated to the latex properties compared to the P content.

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